Ch4 Multiplexing

and

Multiple Access

How to increase:

Throughput

of the communication resources

- Increase EIRP or reduce losses.
- Provide more band width.
- Efficient use of resources.

Multiplexing

Multiplexing

- Sending several signals
  - from different sources
    - to various destinations
      - By regular method
      - or non regular method
    - Through a single channel
      - To increase system capacity

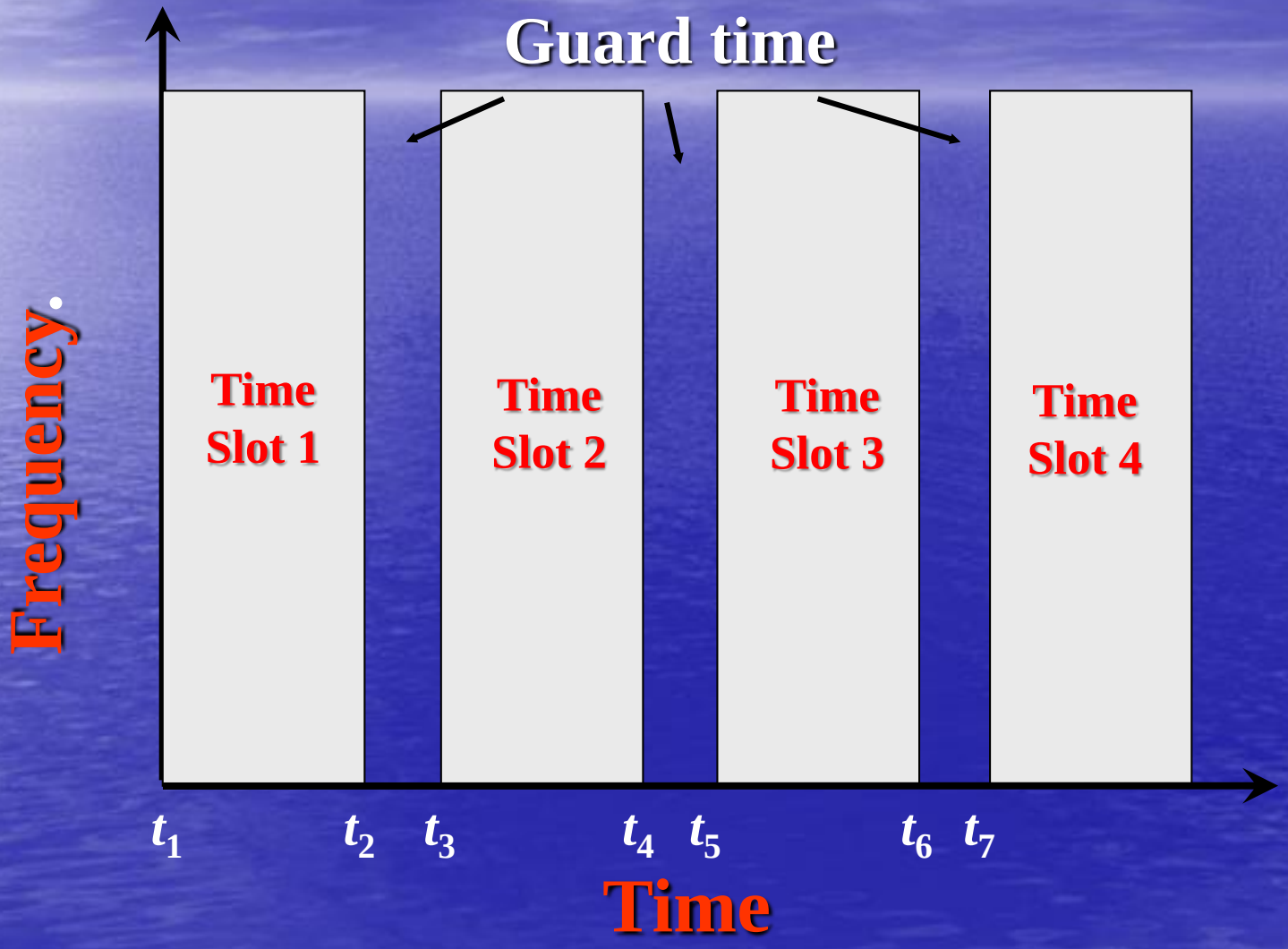
Types of Multiplexing

Types of Multiplexing

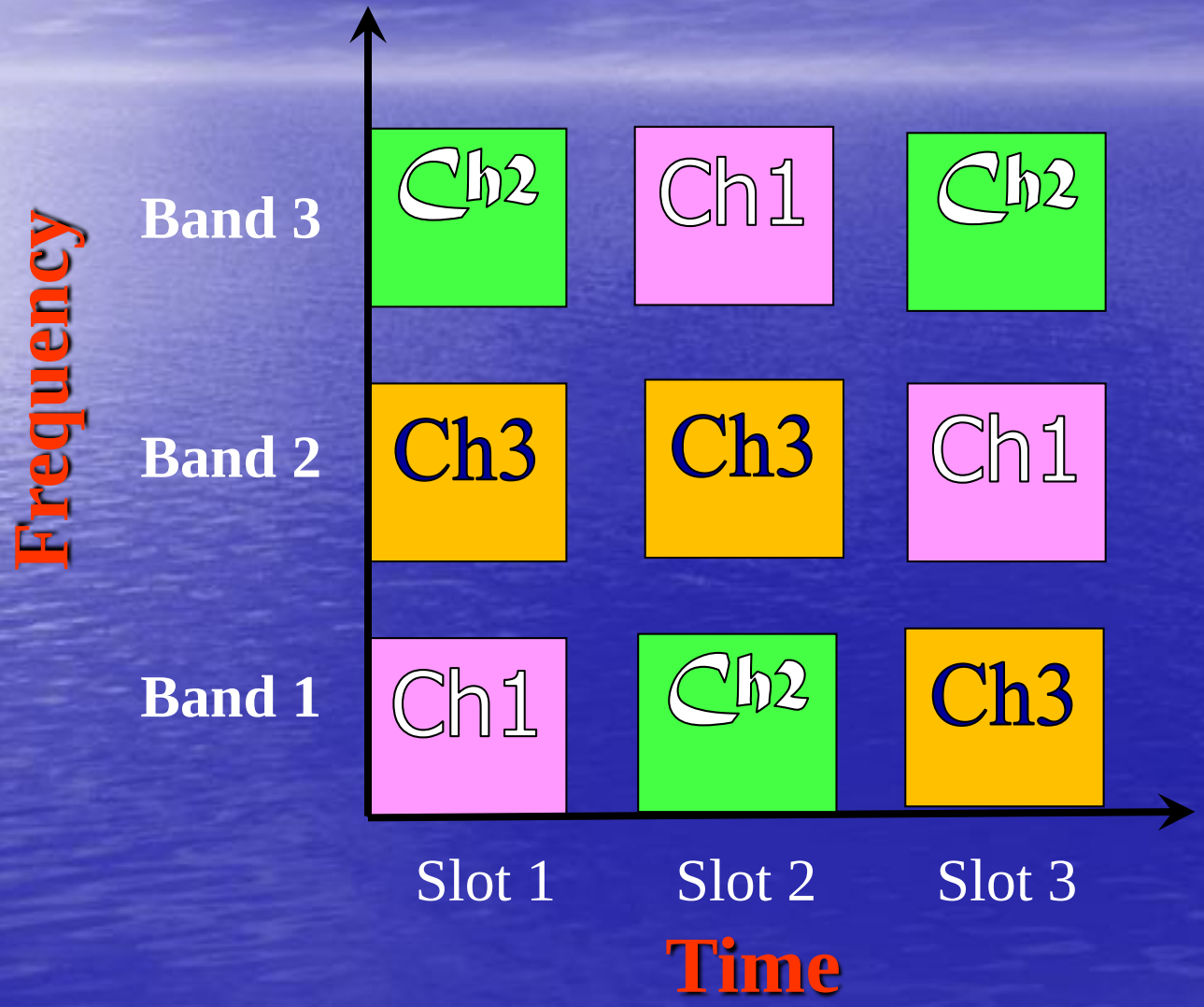
- Frequency Division Multiplexing (FDM)
- Time Division Multiplexing (TDM)
- Code Division Multiplexing (CDM)
- Space Division Multiplexing (SDM)
- Polarization Division Multiplexing (PDM)

Frequency Division Multiplexing FDM

Time Division Multiplexing TDM

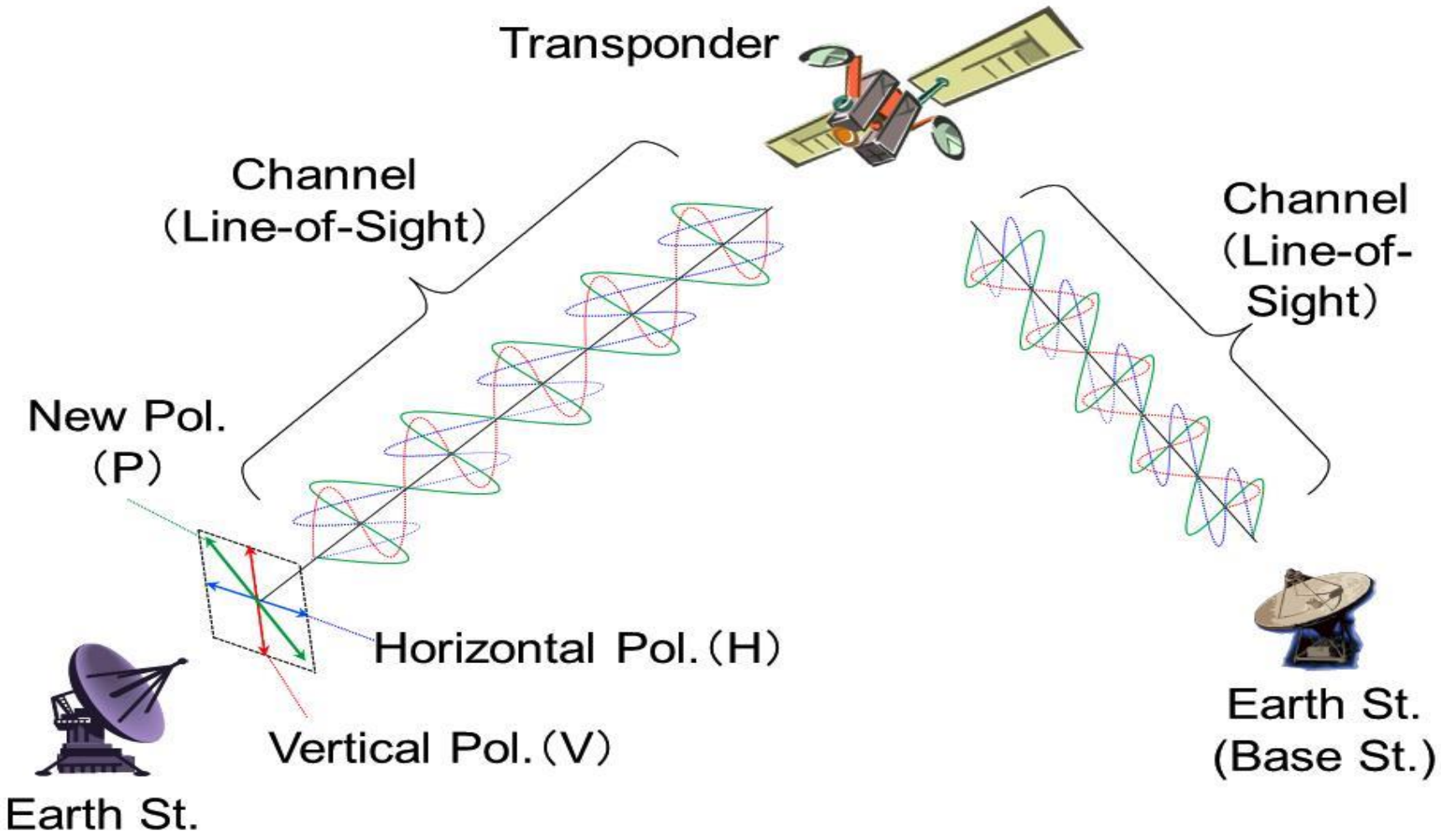


Code Division Multiplexing CDM



Space Division Multiplexing SDM

Polarization Division Multiplexing PDM



FDM

Frequency Division Multiplexing

FDM

- Analogue: Both inputs and outputs.
- Channel should exceed individuals.

$$BW_{ch} \geq BW_1 + BW_2 + BW_3 + \ldots + BW_n$$

- At transmitter:
  - Every signal is modulated at different carrier.
  - SSB is used (lower or upper).
  - Guard bands are used to reduce interference.
- On Reception:
  - Filters are used to separate individuals.
  - Original signal is recovered by demodulation.

Multiplexing of 3 Voice Channel

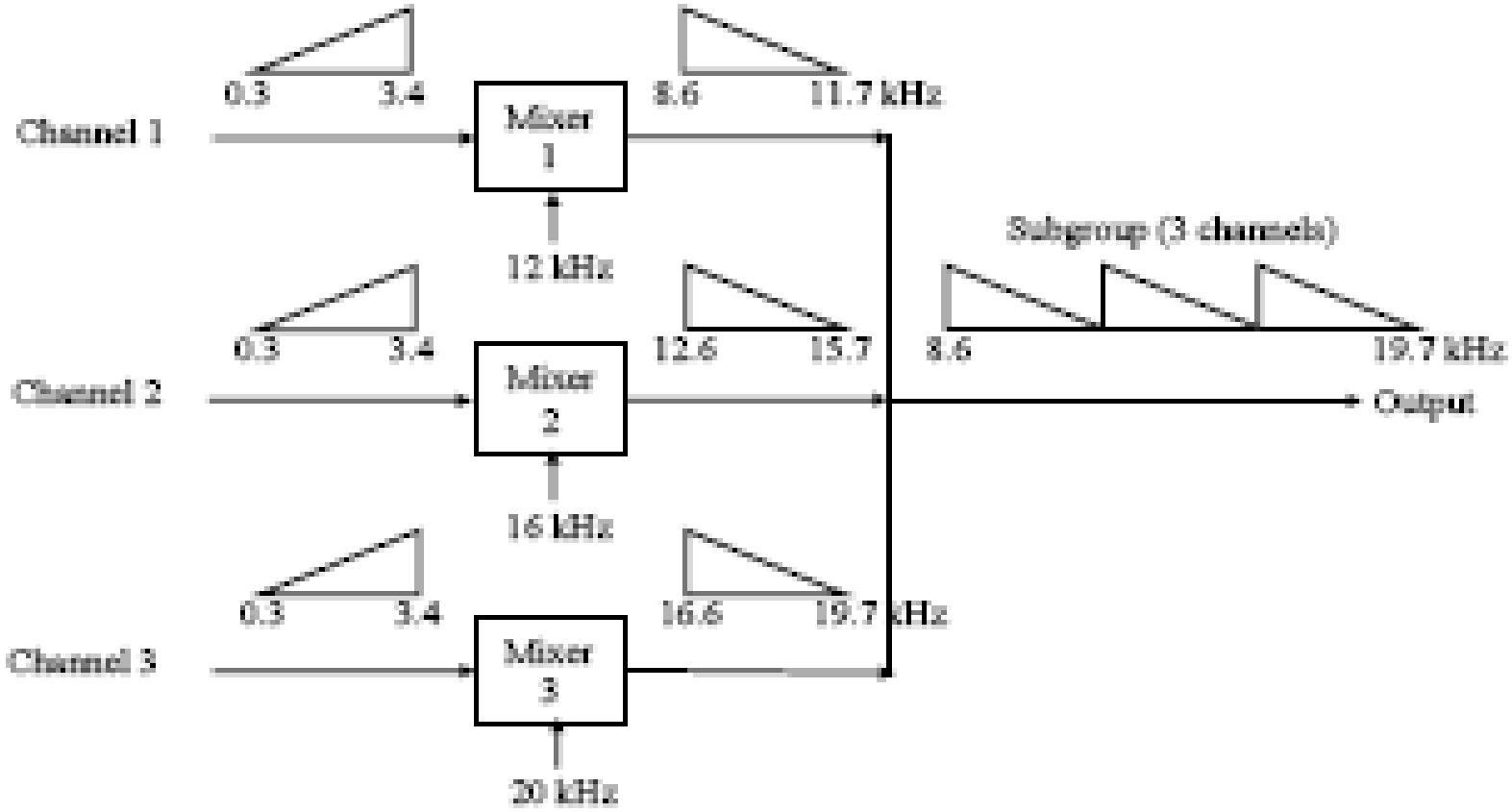
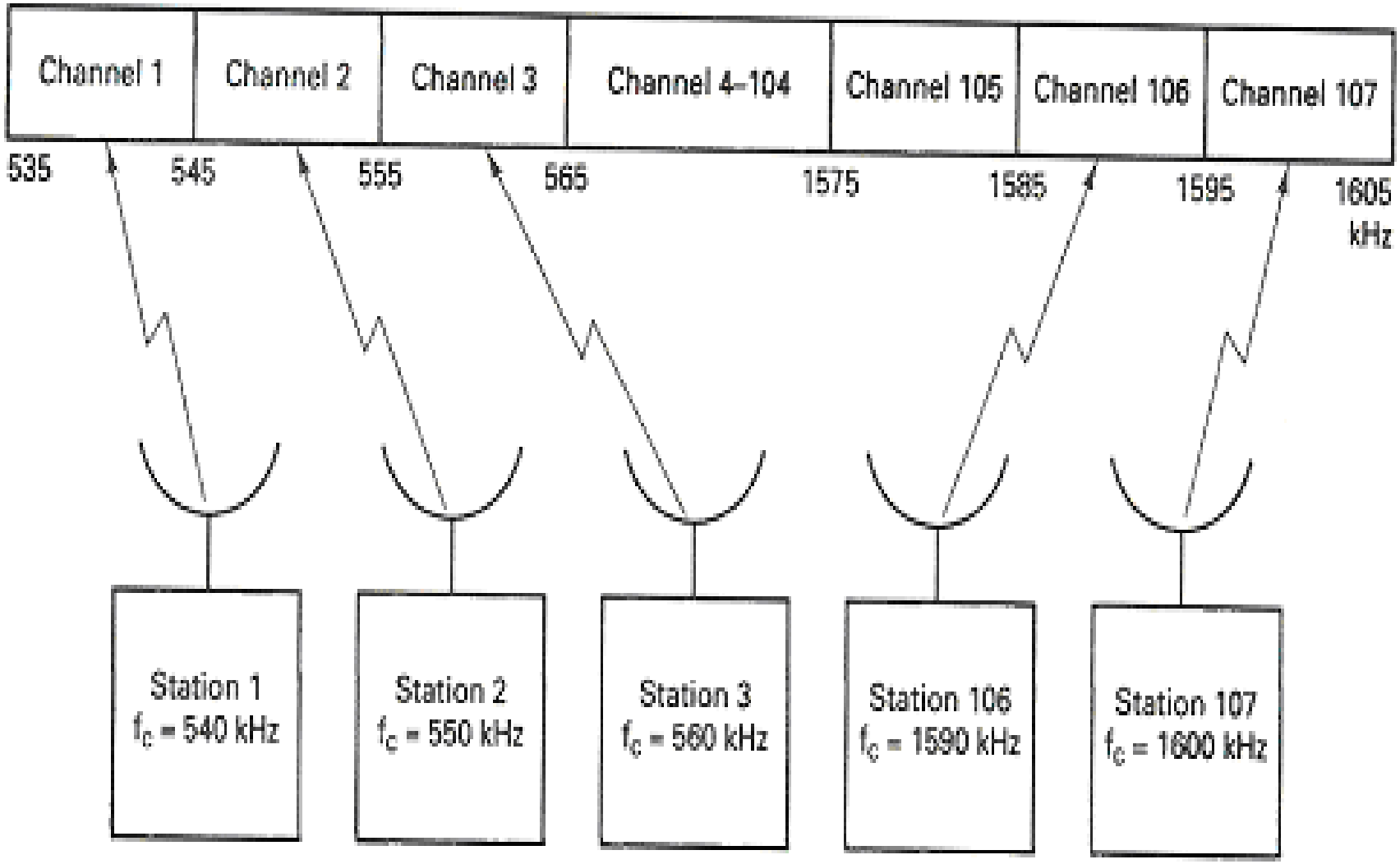


Fig.3.2 FDM Example to Produce One Subgroup Consists of 3 Channels

FDM Applications

- AM Broadcasting:
  - Each channel needs 10KHz via DSB-TC.
  - Bandwidth :535 – 1605 KHz.
- TV Broadcasting:
  - Using coaxial cables
  - Each channel occupies 9 MHZ with VSB
  - VHF, UHF.
- Telephone:
  - Europe: ITU-T .
  - USA: AT&T.

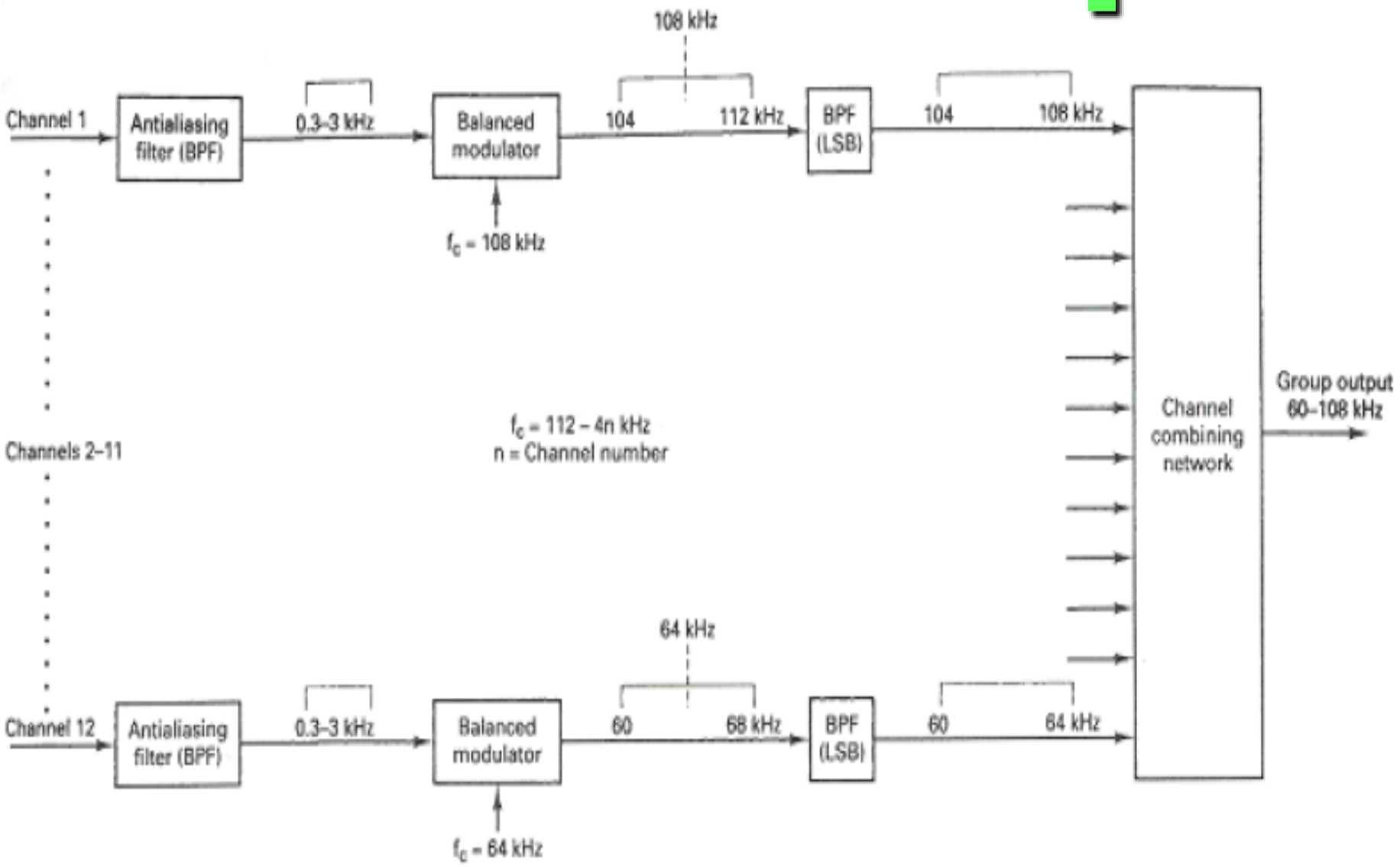


Frequency-division multiplexing commercial AM broadcast band stations

AT&T-FDM Plan
First Level

- **Basic Group**
  - Consists of 12 voice channels.
  - Each channel of 4KHz (0.3:3.4KHZ)
  - Carriers: 64, 68, 72, 76, 80, 84, 88, 92, 96, 100, 104, 108 kHz.
  - Using LSB (USB is suppressed)
  - Basic Group:
    - Extends: 60 - 108 kHz
    - Bandwidth = 108 - 60 = 48 kHz

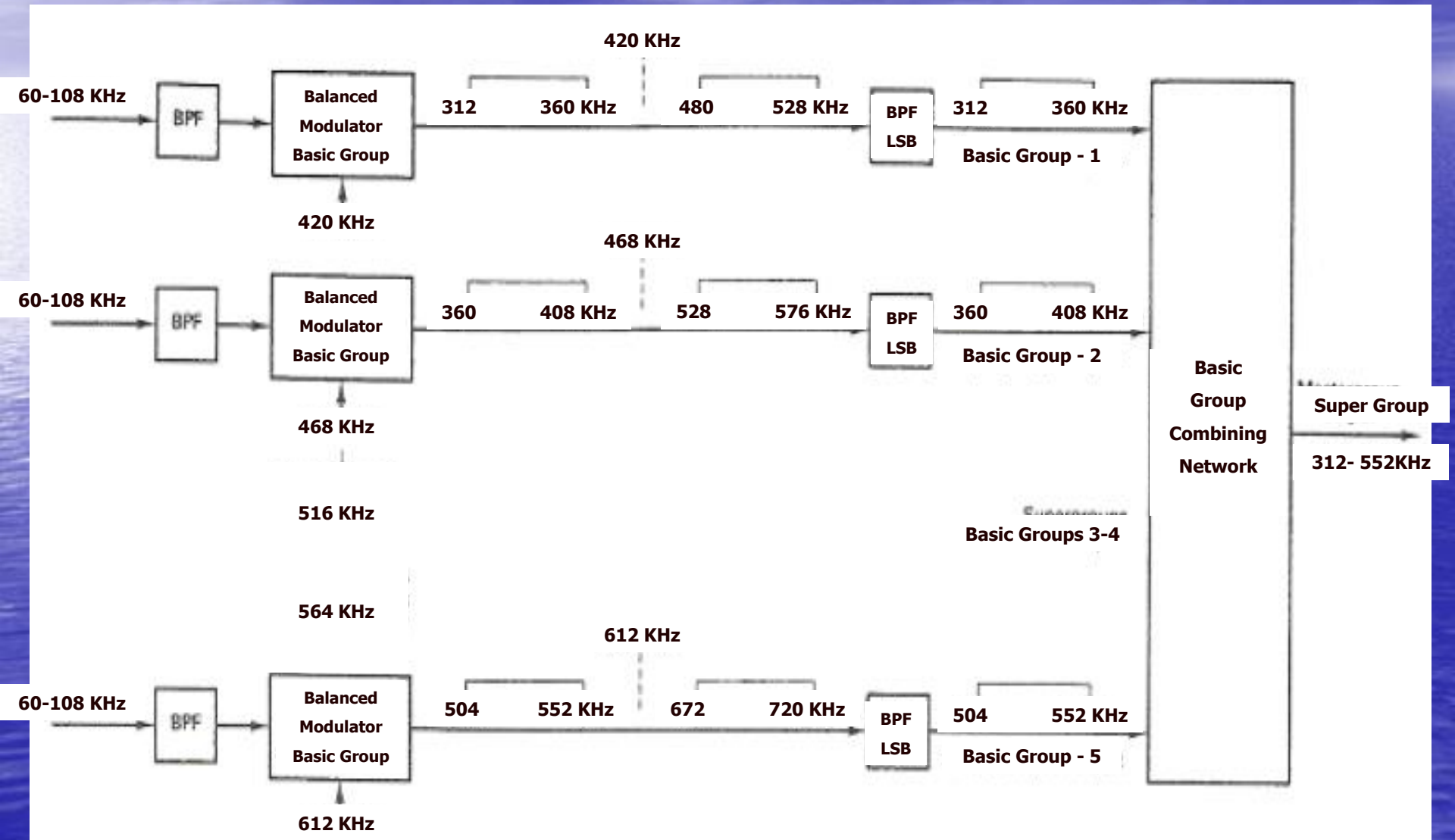
Basic Group


108 kHz
Channel 1
Antialiasing filter (BPF)
0.3–3 kHz
Balanced modulator
104
112 kHz
BPF (LSB)
104
108 kHz
f_c = 108 kHz
Channels 2–11
$f_c = 112 - 4n$ kHz
n = Channel number
Channel combining network
Group output 60–108 kHz
64 kHz
Channel 12
Antialiasing filter (BPF)
0.3–3 kHz
Balanced modulator
60
68 kHz
BPF (LSB)
60
64 kHz
f_c = 64 kHz

Second Level

- Super Group
  - Consists of 5 Groups each of band: 60-108KHz.
  - Modulated by carriers; 420, 468, 516, 564, 612KHz
  - LSB is selected using BPF
  - Bandwidth of Super Group
    - Extends: 312 – 552 kHz
    - Bandwidth = 552 – 312 = 240 kHz
  - No of voice channels = 5 x 12 = 60 channels
  - Or data a medium rate of 50 kbps

Super Group

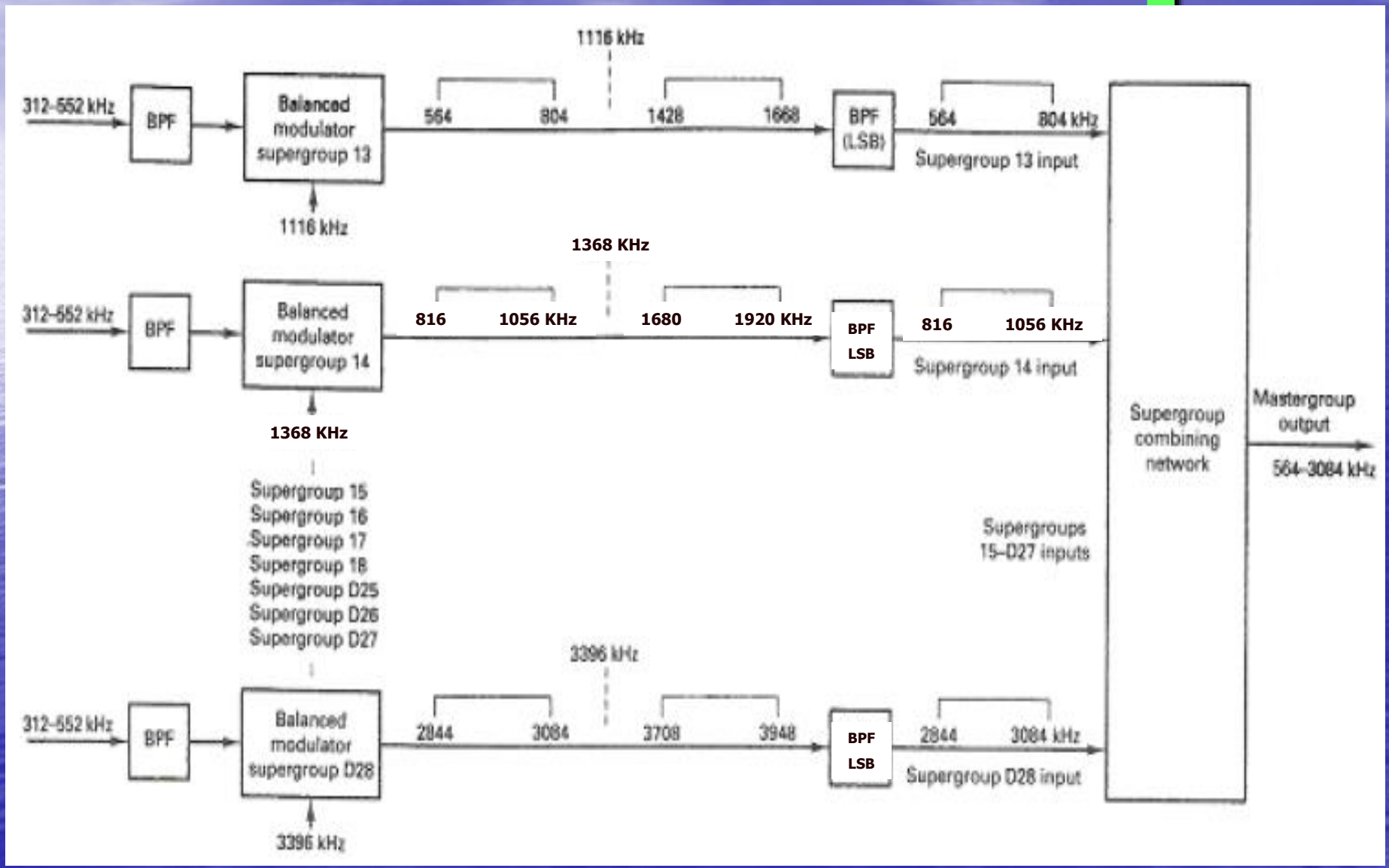

420 KHz
60-108 KHz
BPF
Balanced Modulator Basic Group
312
360 KHz
480
528 KHz
BPF LSB
312
360 KHz
Basic Group - 1
420 KHz
468 KHz
60-108 KHz
BPF
Balanced Modulator Basic Group
360
408 KHz
528
576 KHz
BPF LSB
360
408 KHz
Basic Group - 2
468 KHz
Basic Group Combining Network
Super Group
312- 552KHz
516 KHz
Basic Groups 3-4
564 KHz
612 KHz
60-108 KHz
BPF
Balanced Modulator Basic Group
504
552 KHz
672
720 KHz
BPF LSB
504
552 KHz
Basic Group - 5
612 KHz

Third Level

Master Group

- Consists of 10 Super Groups: band: 312-552kHz.
- Carriers; 1116, 1368, 1620, 1872, 2124, 2376, 2628, 2880, 3132, 3396 KHz.
- LSB is selected using BPF
- Bandwidth of Super Group
  - Extends: 564 – 3084 kHz
  - Bandwidth = 3084 – 564 = 2520 kHz
- No of voice channels = 10 x 60 = 600 channels
- Or data a high rate of 250 kbps

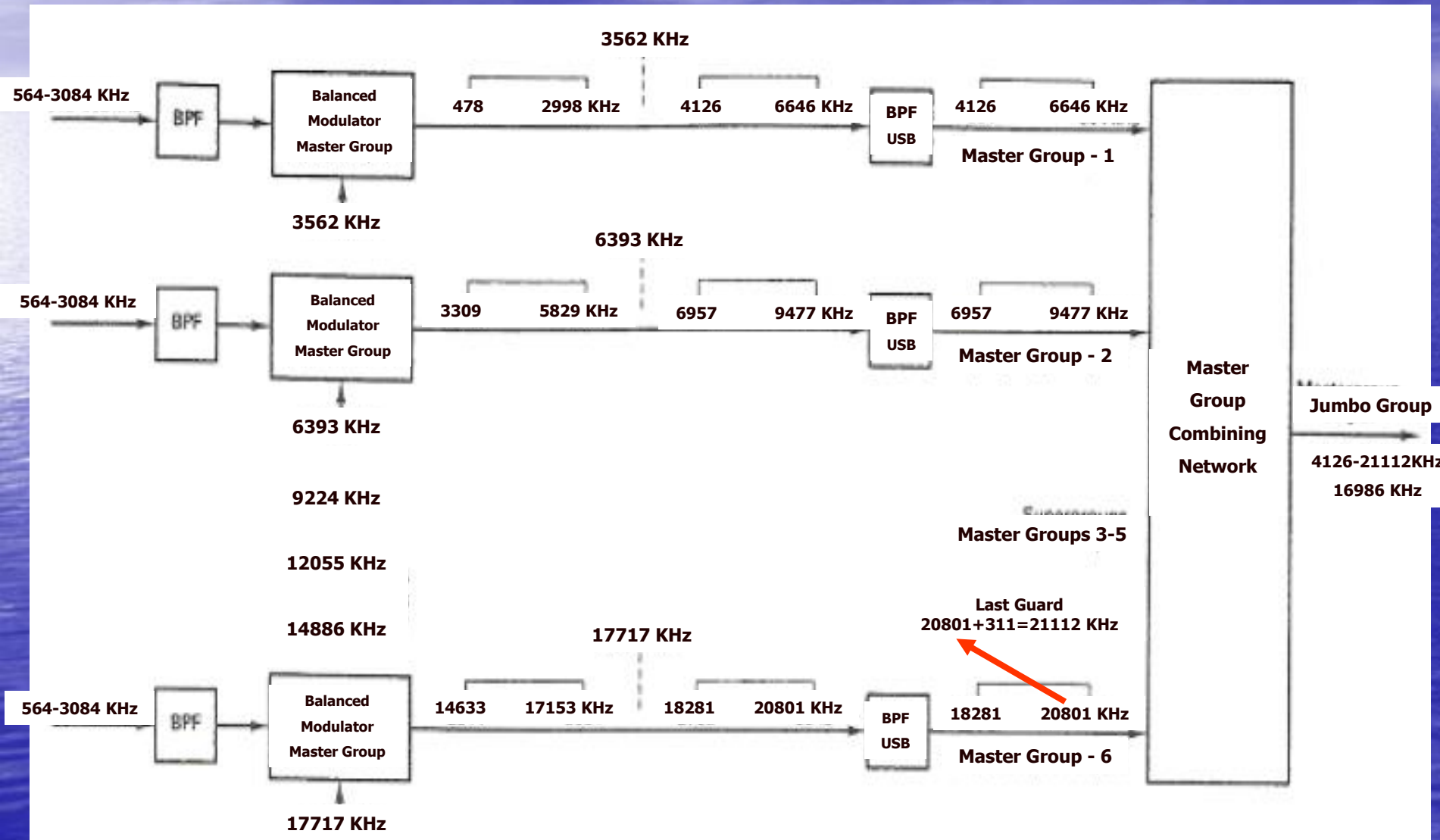
Master Group



Forth Level

- Jumbo Group
  - Consists of 6 Master Groups: band: 564-3084kHz.
  - Carriers; .
  - USB is selected using BPF
  - Bandwidth of Super Group
    - Extends: 4126 – 21112 kHz
    - Bandwidth = 2520 x 6 + 1860 = 16980 kHz
  - No of voice channels = 6 x 600 = 3600 channels
- Super Jumbo Group
  - No of voice channels = 3 x 3600 = 10800 voice

Jumbo Group


3562 KHz
564-3084 KHz
BPF
Balanced Modulator Master Group
3562 KHz
478
2998 KHz
4126
6646 KHz
BPF USB
4126
6646 KHz
Master Group - 1
6393 KHz
564-3084 KHz
BPF
Balanced Modulator Master Group
6393 KHz
3309
5829 KHz
6957
9477 KHz
BPF USB
6957
9477 KHz
Master Group - 2
9224 KHz
Master Groups 3-5
12055 KHz
Last Guard
20801+311=21112 KHz
14886 KHz
17717 KHz
564-3084 KHz
BPF
Balanced Modulator Master Group
17717 KHz
14633
17153 KHz
18281
20801 KHz
BPF USB
18281
20801 KHz
Master Group - 6
Master Group Combining Network
Jumbo Group
4126-21112KHz
16986 KHz

Multiple Access

Geostationary Satellite

- Satellite in circular orbit, at same plane as earth's equatorial plane.
- At altitude where orbital period is identical to earth rotational period.
- It appear stationary, 3 satellites spaced 120° apart can provide worldwide coverage (except for polar regions).

C Band and Transponders

- Most popular band for commercial satellite communications:
  - 6 GHz carrier for uplink and
  - 4 GHz carrier for the downlink.
- Each satellite is to use a 500MHz.
- This wide band is divided into 12 transponders with a bandwidth of 36 MHz each.

FDMA

- Most common 36MHz transponder operates in an FDM/FM/FDMA multi-destination mode.
- A Composite FDM channels are FM modulated and transmitted to satellite within bandwidth allocation of FDMA plan.

FDM/FM/FDMA

- **FDM**: 12 voice channels each of 4kHz SSB spectrum (including guard) are FDM'd to form one group 60-108kHz. 5 groups are FDM'd to form one super group (60 voice; 5x12) from 312-552 kHz.
- **FM**: composite signal is frequency modulated onto a carrier and transmitted to satellite as one access.
- **FDMA**: Satellite receives composite signals from different access (earth stations). So, subdivision of 36MHz transponder may be assigned to different stations (users). Each station (user) receives a specific bandwidth allocation whereby it can access the transponder.

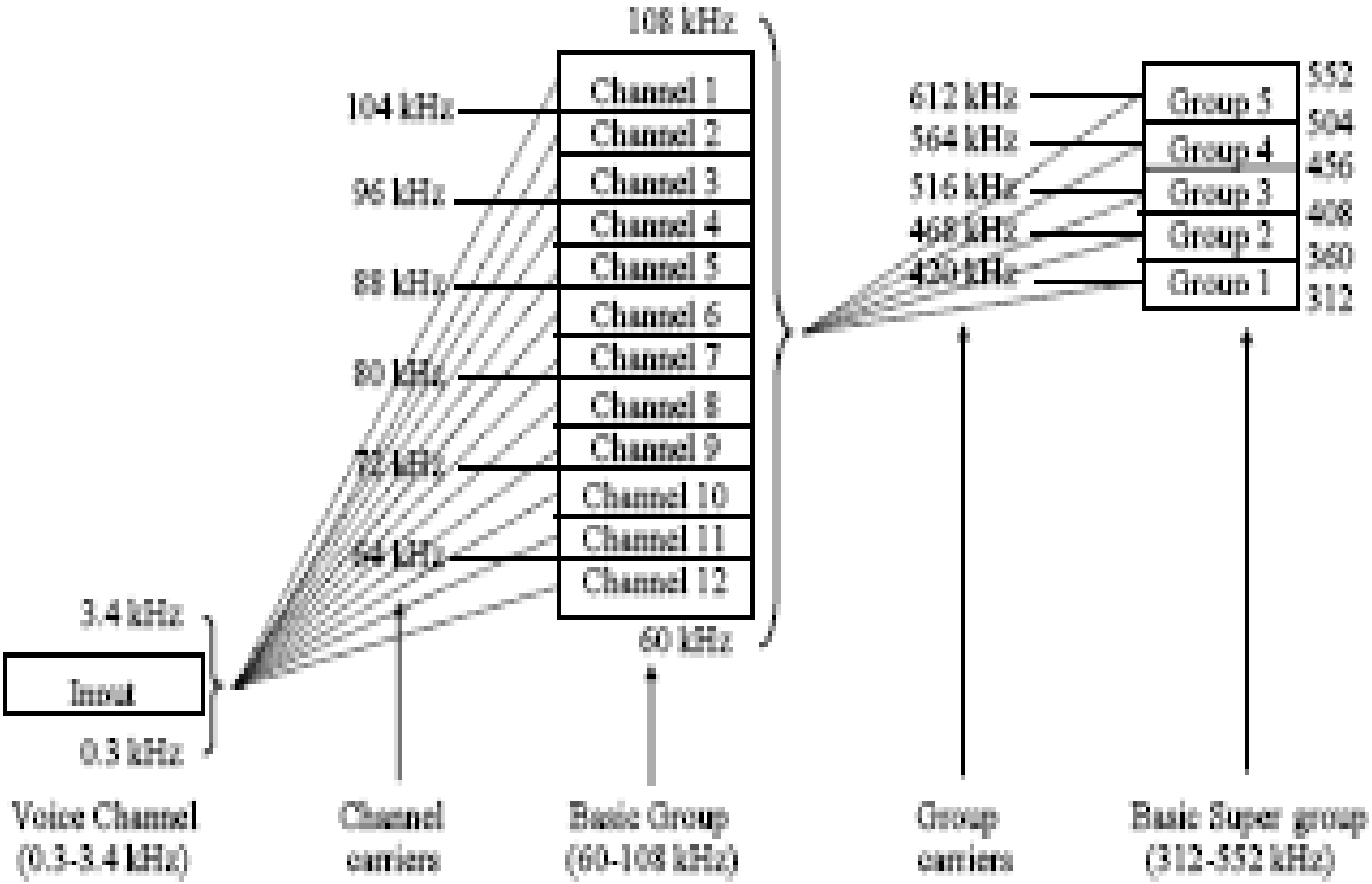


Fig.3.3 Modulation Plan of FDMA Systems

TDM

Time Division Multiplexing

Satellite TDMA

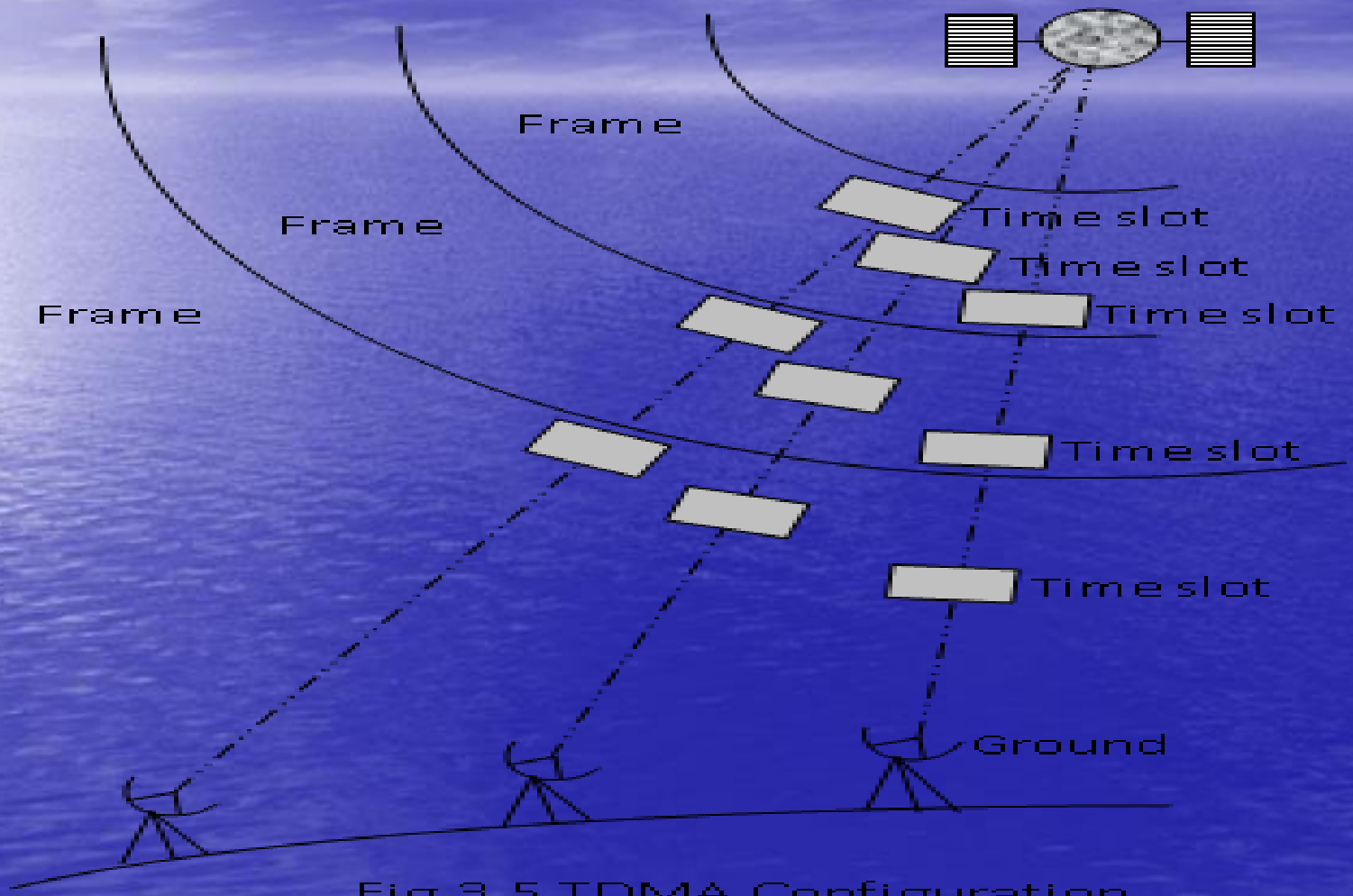


Fig.3.5 TDMA Configuration

CDMA

Code Division Multiple Access

CDMA

- CDMA is a hybrid combination of FDMA and TDMA.
- CDMA is an application of the spread spectrum techniques that are basically classified as:
  - Direct sequence spread spectrum
  - Frequency hopping spread spectrum

Advantages of CDMA

- Privacy: Transmission is easily be intercepted by unauthorized users without code
- Fading is shared among all users:
  - DSMA: Fading randomly affects portions of frequency range.
  - In FH, only during time a user hops into affected portion of spectrum will experience degradation.
- Jam resistance.
- Flexibility: need no precise time coordination among various transmitters (synchronization is only required between a transmitter and a receiver within a group).

DAMA

Demand Assignment Multiple Access

Fixed and Demand

- Fixed-assignment when a station has periodic access to channel independent of its need.
- Demand-assignment give the station access to the channel only when it requests service.
- If traffic tends to be burst-like, demand-assignment may be much more efficient.
- Using buffers and DAMA, system with reduced average capacity can handle burst traffic at the cost of some queuing delay.
- Fixed system capacity equals the sum of the user requirements.
- Dynamic capacity is equal to the average.

Multiple Access Protocols

- One earth station is designated as the master (the controller).
- Control is distributed among all the earth stations.
- Satellite is the controller

One Master Station

- This station possesses a multiple access computer program responds to the service requests of all other users.
- A user's request entails a transmission through the satellite and back down to the controller.
- The controller's response entails another transmission through the satellite.
- So, there are two up- and downlink transmissions for each service assignment.
- **Two round trips per request.**

Distributed Control

- Control is distributed among all the earth stations.
- Each station use same algorithm and have identical knowledge regarding access requests and assignments.
- So, only one round trip is required for each service request

Satellite Control

- Satellite is the controller
- A service request goes from user to satellite, and the response from the satellite can follow immediately.
- So, one round trip is required.

Demand Assignment Operation

1. **Channelization:** Allocation of channels: 1 to N for Army and N+1 for the Navy, etc.
2. **Network state:** A station is advised regarding availability of communications resource and where in the source (e.g., time, frequency, code) to transmit its service request(s).
3. **Service request:** The station makes its request(s) for service.
4. **Schedule:** The controller sends the station a schedule regarding where and when to position its data.
5. **Data:** The station transmits its data.

Demand Assignment Information Flow